ECOSYSTEM TRADE-OFFS IN MANAGING NEW ENGLAND FISHERIES

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ABSTRACT

We describe some recent experiences with ecosystem trade-offs in managing marine fisheries in New England. Conflicting legislative mandates to conserve fishery resources while sustaining fisheries, protecting essential fish habitat, and promoting the recovery of protected species are underlying themes. In the Atlantic sea-scallop fishery, spatial management approaches are promising but require trade-offs with groundfish closed areas and protection of essential fish habitat. Rebuilding groundfish stocks and promoting the recovery of endangered and threatened species have conflicted with traditional policies of allowing unrestricted access to fishing grounds. For the Atlantic herring and mackerel fisheries, we describe trade-offs between maintaining these abundant pelagic stocks and minimizing forgone yields and negative fishery feedbacks. Although applying a holistic ecosystem approach to management of New England marine fisheries should reduce conflicts and improve stakeholder satisfaction, such an approach will, in practice, be tempered by political interests and the willingness of the public to pay for increased management and resource costs.

Worldwide, awareness is growing of the need to manage fishery systems in an ecosystem context (Ecological Society of America, 1998; National Research Council, 1999a; University of Alaska Sea Grant, 1999; Sinclair and Valdimarsson, 2003). This awareness reflects a shift in focus from efficiently extracting resources to restoring and sustaining marine ecosystems that produce benefits. The shift to a more responsible governance of fishery systems will require both conservation of fishery resources and ecosystem protection (Sissenwine and Mace, 2003).

In the U.S., fishery resource conservation is mandated by the Magnuson-Stevens Fishery Conservation and Management Act (The Magnuson Fishery Conservation and Management Act of 1976 was amended by the Sustainable Fisheries Act in 1996 to become the Magnuson-Stevens Fishery Conservation and Management Act of 1996, hereafter referred to as the “Magnuson Act”). Although the current Magnuson Act requires protection of essential fish habitat, protection of ecosystems is not emphasized. In fact, the term “ecosystem” does not even appear in the National Standards for Fishery Conservation and Management (National Research Council, 1999a). Nonetheless, “taking into account the protection of marine ecosystems” (National Oceanic and Atmospheric Administration, 1996) is listed as a potential reason to reduce optimum yield below maximum sustainable yield (see Fluharty, 2000). Although the Magnuson Act lacks a clear mandate to protect ecosystems, it suggests the intent to maintain ecosystem quality and to sustain associated benefits. If we are actually to move forward and implement ecosystem-based management, tangible goals and more reliable and effective management institutions will be needed (Brodziak and Link, 2002). In this context, multiple goals will commonly be needed to represent marine ecosystem complexity and diverse stakeholder values.

Making trade-off decisions is a natural outcome of having multiple goals for managing human activities within an ecosystem. Here, we describe some recent experiences with ecosystem trade-offs in managing New England fisheries. We begin by discussing

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conflicting legislative mandates for U.S. fisheries. We then describe specific trade-offs in managing sea-scallop, groundfish, and pelagic fisheries. The implications of ecosystem trade-offs in these fisheries are discussed, and both short-term impediments and long-term benefits of implementing ecosystem-based management of New England fisheries are identified.

Conflicting Mandates

The existing lack of coherence between federal laws governing uses of U.S. marine resources creates conflicting mandates. The problem is exacerbated by a lack of coordination among agencies responsible for implementing the laws. The National Marine Fisheries Service (NMFS) has sole or joint responsibility for implementation of five major independent pieces of legislation. The Magnuson Act calls for sound management of the fishery resources of the U.S., with an emphasis on preventing or ending overfishing, rebuilding overfished stocks, protecting essential fish habitats, and realizing the full potential of the nation's fishery resources. The Marine Mammal Protection Act (last amended in 1994) requires minimization of human-induced mortality of all marine mammals. The Endangered Species Act (last amended in 1988) calls for protection of plants and animals listed by the federal government as "endangered" or "threatened." The National Environmental Policy Act (last amended in 1982) requires environmental assessments of proposed regulations and analyses of alternative means of achieving similar ends. The Regulatory Flexibility Act (last amended in 1996) requires federal agencies to review regulatory impacts on small businesses and to consider less burdensome alternatives.

Even within the Magnuson Act, potential conflicts arise between the 10 National Standards for Fishery Conservation and Management. National Standard 1 mandates that conservation and management measures shall prevent overfishing while achieving optimum yield. By itself, this standard can create conflicts because the nature and ranking of the ecological, economic, and social factors that determine optimum yield are not specified. When it is combined with other requirements such as National Standard 5 (which addresses economic efficiency), National Standard 9 (which requires minimization of by-catch), and in particular, National Standard 8 (which requires the needs of fishing communities to be taken into account), the balance between objectives may be difficult to achieve. Stringent Marine Mammal Protection Act and Endangered Species Act requirements to minimize mortality of protected and threatened or endangered species introduce another potential source of conflict. These acts are often at odds with the Magnuson Act goal of achieving optimum yield in fisheries where by-catch of protected or endangered species occurs.

In New England, however, relatively few clashes have arisen to date between fishing activities and minimizing mortality of protected species. One exception is the conflict between protecting North Atlantic right whales (*Eubalena glacialis*), of which only about 325 individuals remain, and the prosecution of lobster-trap and sink-gill-net fisheries in areas frequented by right whales. Current regulations require gear adjustments, seasonal closures, and dynamic area closures for both fisheries. Another exception is the use of net pingers and seasonal closed areas to minimize harbor porpoise (*Phocoena phocoena*) by-catch in New England gill-net fisheries. Incidental gill-net fishery takes have been reduced from over 2000 animals in 1994 to 80 animals in 2001, far below the potential biological removals for this protected species (727 animals).

One reason that conflicts between competing objectives have not occurred more frequently is that many New England fishery resources have been overfished for such a long time (e.g., four decades or more in several instances). In these cases, the most pervasive problem was, and remains, to rebuild overfished stocks while maintaining viable commercial fisheries.

Trade-Offs in Scallop Fisheries

Background.—The Atlantic sea scallop (*Placopecten magellanicus*) fishery is the second most valuable commercial capture fishery in the northeast U.S. Owing to the high ex-vessel value of scallops, the fishing fleet grew rapidly during the 1980s. Landings peaked at about 10,000 mt in 1990. Fishing effort more than doubled between 1985 and 1991, reaching nearly 22,000 d fished in 1991–1992 (Fig. 1). Fishing effort is now controlled by allocation of days at sea to scallop vessels. During 1998–2001, sea-scallop fishing effort has been much lower, ranging between 5000 and 7000 fishing days.

The rapid growth of sea scallops, variable recruitment, and excess fleet capacity historically resulted in a recruitment-driven fishery. Scallop recruitment pulses were rapidly fished, and fleet activity frequently shifted between Mid-Atlantic and Georges Bank stock areas to harvest localized scallop concentrations.

Regulations imposed since the Atlantic sea scallop fishery management plan (FMP) was implemented in 1982 have included reductions in days at sea, a maximum crew size, various gear modifications, and minimum average size requirements. A major management turning point occurred in December 1994 when three year-round closed areas were established on Georges Bank to provide protection for depleted groundfish stocks (Murawski et al., 2000). These closures excluded all fishing gears capable of catching groundfish, including scallop dredges. The groundfish closed areas redirected scallop effort from inside to outside the closed areas. As a result, scallop fishing effort was concentrated into smaller areas.

The groundfish area closures had an unintended beneficial effect on Georges Bank scallop biomass (Fig. 1). Since 1995, overall biomass has increased more than fourfold; within closed areas, increases have been roughly 10-fold. The dramatic increase in scallop biomass combined with limited spatiotemporal openings of the closed areas substantially increased scallop fishery yields, landings per unit effort (Fig. 1), and profits.

Scallop-Fishery Yields vs Essential Fish Habitat.—On the basis of the successful rebuilding of scallops within closed areas, a rotational area management approach for scallops is currently being developed in an FMP amendment. Requirements to identify and protect essential fish habitat for scallops, groundfish, and other species are an important and contentious part of the proposed amendment. The trade-off is between how much habitat to keep open for the scallop fishery and how much to protect for groundfish, scallops, and other species.

Closed-area management has probably improved groundfish habitat by permitting the recovery of benthic habitats and emergent epifauna (National Research Council, 2002). Abundance and recruitment of Georges Bank haddock (*Melanogrammus aeglefinus*) and yellowtail flounder (*Limanda ferrugineus*) have both improved coincident with the enactment of area closures, reduced days at sea, and other management measures (Murawski et al., 2000; Brodziak and Link, 2002). Although the conservation benefits of year-round closure of approximately 17,000 km^2 of fishing grounds to mobile fishing

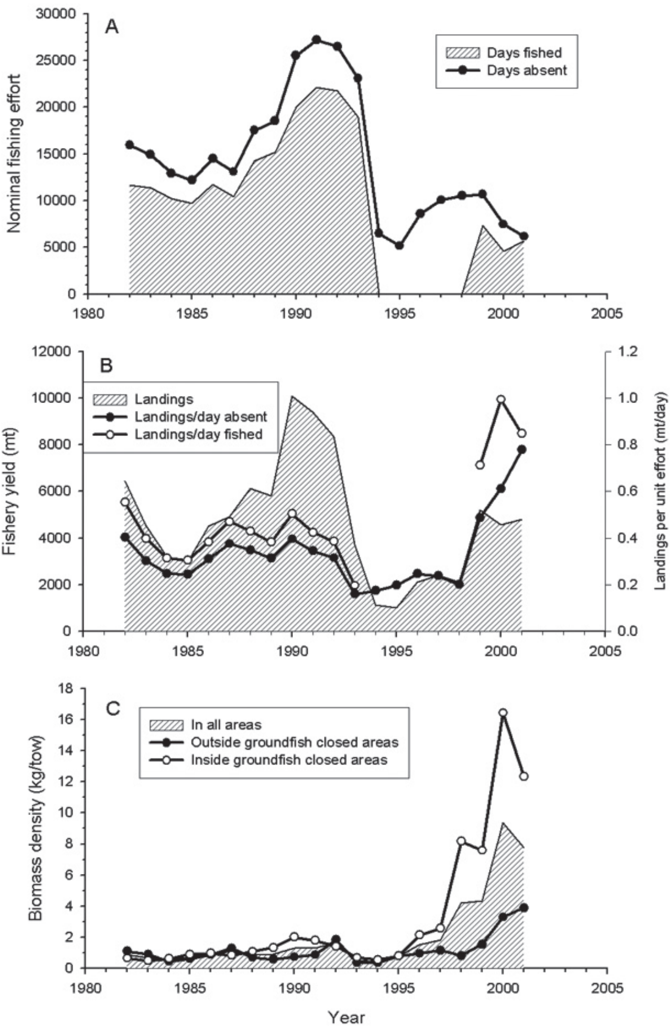


Figure 1. (A) Atlantic sea-scallop nominal fishing effort as indexed by reported days that a sea-scallop-fishing vessel was actively fishing (days fished) and reported days that a sea-scallop-fishing vessel was absent (days absent) from port. (B) Fishery yield and landings per day fished and day absent. (C) Scallop biomass density in all areas, in groundfish closed areas, and outside groundfish closed areas as measured by research surveys, 1982–2001. Because of changes in vessel reporting requirements, no data on reported days fished were collected during 1994–1998.

gear have probably been substantial, they are difficult to quantify because of a lack of data and confounding factors.

The quantitative effects of scallop fishing gear on habitat have not been extensively studied, but evidence is growing that trawling and dredging can have negative impacts on seafloor habitats and benthic communities (National Research Council, 2002). Although some direct impacts such as reduced habitat complexity and altered benthic community structure have been documented (Collie et al., 1997, 2000a), the long-term effects of dredge-induced changes in temperate seafloor habitats are still being investigated (Collie et al., 2000b).

The spatial distribution of sea scallops has important implications for trade-offs between scallop fishery yields and both habitat and by-catch. Areas of high scallop density, commonly called "beds," tend to be well-defined, persistent patches on high-energy bottoms. Until recently, precise information on the spatial locations of scallop beds was obtainable only by direct observation such as fishing. Acoustic methods for identifying potential habitat are now available, however. Multibeam acoustics has been successfully applied to mapping scallop beds on Browns Bank, Canada. By applying fine-scale mapping of beds, the Canadian scallop fishery on Brown's Bank was able to reduce fishing time and towing distance by 70% between 1998 and 1999 while still harvesting the same scallop quota (National Research Council, 2002). If such fine-scale mapping of U.S. waters becomes available in the future, high-density scallop beds could be fished and the footprint of the fishery reduced while yield is maintained. Replacing diffuse, low-performance scallop fishing effort with spatially concentrated, high-performance effort would reduce the potential for habitat alteration and finfish by-catch.

Rotational area management of sea scallops has broad support because of the clear economic advantages of fishing on dense aggregations, the significant reduction in fishing mortality, and the potential for improved habitat protection. Recent openings of groundfish closed areas to allow limited scallop harvests represent ongoing experiments to evaluate fleet behavior, management response, and scientific monitoring. To date, groundfish recovery efforts have taken precedence over sea-scallop harvest, and scallop-vessel access to Georges Bank closed areas has been limited. If future potential yield benefits of rotational areas are not realized because of habitat and by-catch concerns, conflicts between scallop and groundfish fleets are likely to increase.

Shared access to closed areas will be difficult as long as fishing capacities of both scallop and groundfish fleets vastly exceed resource productivity. Closures that simply shift fishing effort to open areas may be detrimental if the recovery from periods of intensive fishing exceeds the rebuilding capacity of the target resource. Rotational area management without a clear delineation of the trade-offs will probably complicate the already challenging interactions among fleets, environmentalists, and managers.

Trade-Offs in Groundfish Fisheries

Background.—New England groundfish fisheries have been productive for hundreds of years, but their productivity has declined through time because of overfishing (see, for example, Sinclair and Murawski, 1997; Murawski et al., 2002). As fish stocks declined, fishing technology steadily improved. As fishing gears became more efficient, target species also changed. Increased efficiency and higher fishing effort eventually led to further declines and depleted stocks.

The pattern of chronic overfishing is epitomized by Georges Bank haddock, which has been overfished by modern standards for decades (Brodziak and Link, 2002). Fishery management was limited before the arrival of the foreign distant-water fleets in the 1960s (Hennemuth and Rockwell, 1987). Immediately after the Magnuson Act was implemented in 1977, the New England Fishery Management Council (NEFMC) established annual catch quotas to conserve New England groundfish stocks. Unfortunately, the quota system was largely ineffective because of noncompliance and lack of enforcement (Hennessey and Healy, 2000). The NEFMC subsequently used indirect control measures (such as gear restrictions, minimum fish sizes, and spawning-season closures) to regulate the New England groundfish fisheries (Fogarty and Murawski, 1998), yet this approach was also ineffective. By the early 1990s, several groundfish stocks had collapsed because of excessive fishing pressure.

Since 1994, several important New England groundfish stocks have increased in abundance in response to direct controls on fishing mortality (i.e., fishing-effort limitations) and other significant conservation measures (i.e., large-scale closed areas and fishing-gear restrictions). Georges Bank yellowtail flounder and Georges Bank haddock stocks have shown substantial recovery (Fig. 2), but the Georges Bank and Gulf of Maine cod (*Gadus morhua*) stocks have shown little recovery and are still being overfished (Fig. 2). Continued overfishing of the cod stocks has generated a major controversy over the efficacy of groundfish management.

Management controversy is hardly new to New England fisheries. In October 1984, the World Court settled a maritime boundary dispute between the U.S. and Canada over the Gulf of Maine area and placed the productive northeast peak of Georges Bank within Canadian waters (Christie, 1987). In 1991, the Conservation Law Foundation sued NMFS for violating National Standard 1 by allowing continued overfishing of New England cod, haddock, and yellowtail flounder stocks (Hennessey and Healey, 2000). Subsequent amendments to the NEFMC multispecies FMP were implemented that were intended to end overfishing and to rebuild groundfish resources, but cod stocks continued to be overfished as target total allowable catches were exceeded by 50% or more (Fig. 3). As a result, another lawsuit was filed in 1999 to force NMFS to cease this overfishing and to develop a by-catch monitoring program. NMFS lost this lawsuit, and the NEFMC is presently crafting Amendment 13 to the multispecies FMP, which will address these inadequacies. In the interim, fishery managers are taking action to comply with court-ordered conservation mandates.

Rebuilding Groundfish Stocks vs Maintaining Fishing Communities.—Substantial reductions in fishing mortality are needed to rebuild the cod stocks (Fig. 2). Both the Gulf of Maine and Georges Bank cod require more than a 50% reduction in fishing mortality to achieve the rebuilding fishing mortality target. The National Standard 1 guideline indicates that stock rebuilding to the biomass that produces long-term potential yield (B_{MSY}) should take no longer than 10 yrs unless life-history characteristics and stock condition make this goal infeasible. For Gulf of Maine cod, the 10-yr rebuilding time frame applies, and the stock must be rebuilt by 2009. The Georges Bank cod stock is so depleted, however, that it cannot be rebuilt in 10 yrs, even in the absence of fishing! Therefore, a longer time frame applies, and in this case, the Georges Bank cod must be rebuilt by 2026.

Given the large reductions in days at sea probably needed to permit recovery of Atlantic cod stocks and the large amount of allocated but unused latent fishing effort (Fig. 2), the question of when rebuilding time frames begin is important for the short-term economic prospects of fishing vessels and fishing communities. The lawsuit filed in 1999 led to a 1999–2009 rebuilding time frame, but some argued that the actual starting point was when the stocks were declared overfished in the NMFS 2003 Report to Congress. A further complication is that in February 2002 NMFS convened a working group to reevaluate biological reference points for New England groundfish so that rebuilding targets would be completely consistent with the stock-assessment methodology. The working group applied new methods and substantially revised biomass reference points for several stocks, including Georges Bank cod and haddock (NEFSC, 2002). The revised reference points were considered unfair by some, who then accused NMFS of “moving the goal posts,” complicating an already controversial situation.

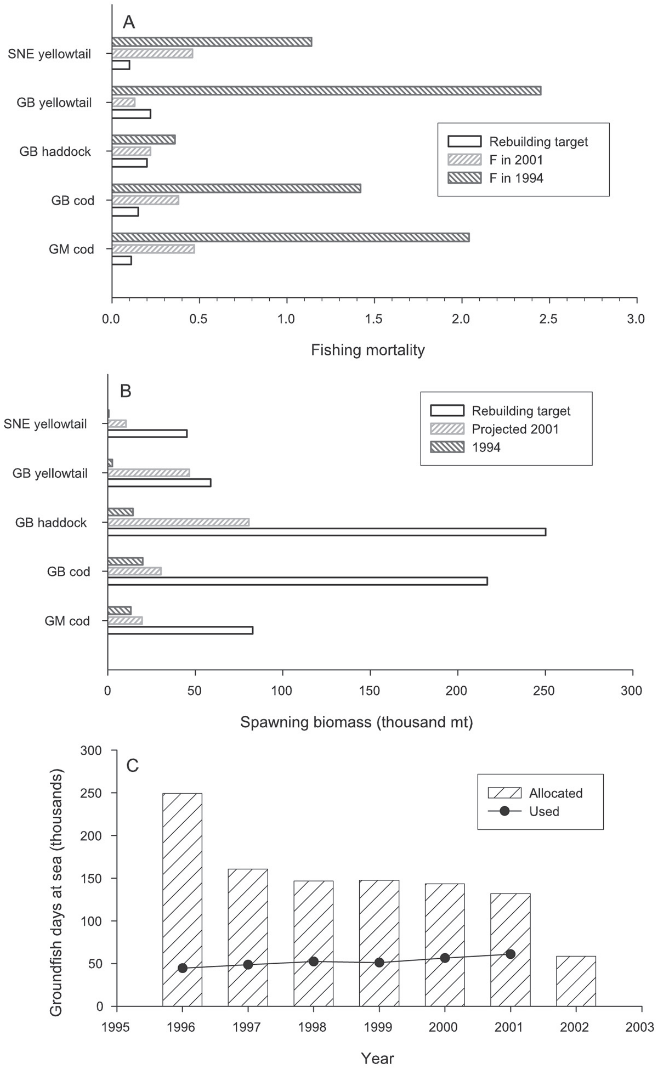


Figure 2. (A) New England groundfish-fishing mortality rebuilding targets, projected 2001 values, and 1994 values for five major stocks. (B) Spawning biomass rebuilding targets, projected 2001 values, and 1994 values for five major stocks. (C) Reported groundfish days-at-sea usage and total allocated days at sea including latent effort by year. SNE, southern New England; GB, Georges Bank; GM, Gulf of Maine.

Forestalling the restrictive conservation measures needed to rebuild stocks has proven to be a viable strategy for maintaining short-term economic interests. Hennesey and Healey (2000) have pointed out that Ludwig's ratchet, the positive feedback between political power and continuing investment in a declining natural resource, provides a good description of the New England groundfish fishery-management process since 1977, but significant reductions in fishing effort will nonetheless occur in the near future either under court order or through the FMP amendment process.

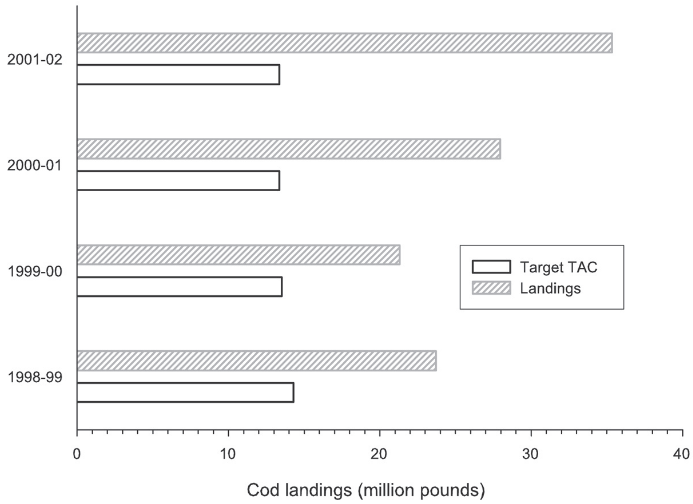


Figure 3. Atlantic cod target total allowable catch (TAC) and landings by fishing year for Georges Bank and Gulf of Maine stocks.

One implication of reducing groundfish-fishing effort is that some fishing firms will not be able to maintain profitability. An indirect implication is that fishery capitalization goals need to be established because no target fleet size exists for New England groundfish. The lack of an appropriate capitalization goal is a serious limitation because open access has been entrenched as management dogma and a substantial amount of latent effort exists. The inertia to improve the match between the number of fishing vessels and the number of fish is a natural outcome of the limited accountability of the NEFMC under the Magnuson Act. Although the NEFMC is more influential in determining what is or is not implemented, NMFS is directly responsible and ends up being sued. The NEFMC therefore has little incentive to move from the status quo to a new regime of sustainable fishing capacity and effort, except by court mandate.

Share-Based Harvesting Rights vs Freedom to Fish.—One of the most effective means of harmonizing fishing effort and resource productivity is through fleet consolidation by means of share-based harvesting rights for harvesters (National Research Council, 1999a). This is an incentive-laden approach but requires an initial allocation of shares amongst stakeholders. Therein lies the trade-off. Implementation of an allocation scheme is an extremely controversial process that few wish to address because it would limit freedom of individuals to fish.

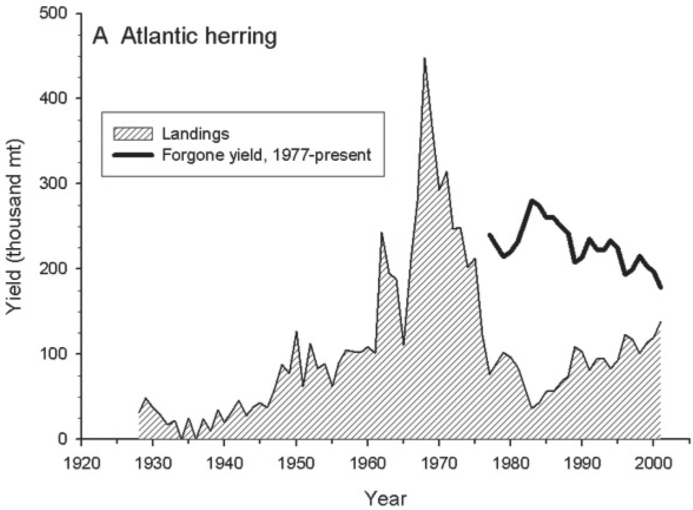
The landscape of stakeholder power may be changing, however. Since the Magnuson Act was passed in 1976, the power base has primarily consisted of industry stakeholders. More recently, environmental organizations and, in some cases, recreational fishing interests have become empowered. These subtle changes in political influence will affect how U.S. fisheries perform over the long term. Both environmental and recreational fishing organizations have used the judicial system to exert their influence (National Academy of Public Administration, 2002). In fact, the U.S. District Court for the District of Columbia's Judge Gladys Kessler has maintained jurisdiction over New England groundfish management as a result of the 1999 environmental organization's lawsuit until Amendment 13 has been completed to the court's satisfaction.

Trade-Offs in Pelagic Fisheries

Background.—Pelagic fish are currently the dominant component of finfish biomass on the continental shelf off New England (Link, 1999; Link and Brodziak, 2002). Atlantic herring (*Clupea harengus*) and Atlantic mackerel (*Scomber scombrus*), each with a stock size of well over a million tons, comprise a large proportion of the pelagic fish component. These two principal pelagics occupy important trophic positions in the northeast's continental shelf ecosystem and are prominent prey in the diets of many predators (Link, 1999). They are important forage for mid-sized predatory fishes such as bluefish (*Pomatomus saltatrix*) and cod and are common prey of many sharks, tunas, billfishes, whales, seals, and seabirds in the region (Overholtz et al., 1991a; Link and Brodziak, 2002). Herring and mackerel have also been the subject of intense fisheries, either historic or current (Fig. 4). Thus, herring and mackerel play a prominent role in both the food web and the fisheries of the region.

Maintaining High Pelagic Biomass vs Negative Fishery Feedbacks.—Herring and mackerel biomasses have increased substantially in recent years (NEFSC, 2001). This increase appears to have reduced growth rates and the size and weight at age of both species (W.J.O., unpubl. data). In this case, density-dependent growth occurs because the per capita ration decreases, leading to a 20–40% reduction in weight at age for these species (Overholtz, 1989). Reduced growth rates affect the pelagic fishery negatively through loss of per capita yield per recruit. Reduced fish size can decrease processing yields, reduce fat content, and make herring or mackerel less attractive to the foreign export market. Maintaining low fishing-mortality rates and high pelagic biomasses can therefore produce density-dependent growth or other compensatory processes (Overholtz et al., 1991b), which will affect the fishery negatively. In contrast, one likely effect of reduced pelagic biomass is an increase in fish size at age, on average. Increased size at age, in turn, could generate an appreciable portion of annual fishery yields from these stocks. One trade-off is therefore between high pelagic biomass and density-dependent population processes.

Other potentially important negative fishery feedback could occur if high herring and mackerel biomasses inhibit the recovery of groundfish through depensatory recruitment or other processes. This is the "cultivation-effects" hypothesis (Walters and Kitchell, 2001), which could be a viable mechanism for reduced groundfish recruitment because both herring and mackerel are planktivores that can consume fish larvae (Ojestad, 1985; Michaels, 1991). Could the prospects for groundfish recovery be substantially limited by herring and mackerel feeding on groundfish eggs and larvae? This is a difficult question to answer definitively because of confounding factors and the absence of long-term field studies. Nonetheless, some recent field research suggests that the cultivation hypothesis may not be particularly important for these species. Mackerel may not be an important source of predation on either cod and haddock larvae because of the limited spatial overlap between migratory mackerel and their potential larval prey (Garrison et al., 2000). On the other hand, herring migratory patterns appear to coincide with the distribution of haddock larvae, although not with that of cod (Garrison et al., 2000). High herring abundance might therefore be expected to have a negative effect on the haddock fishery. If



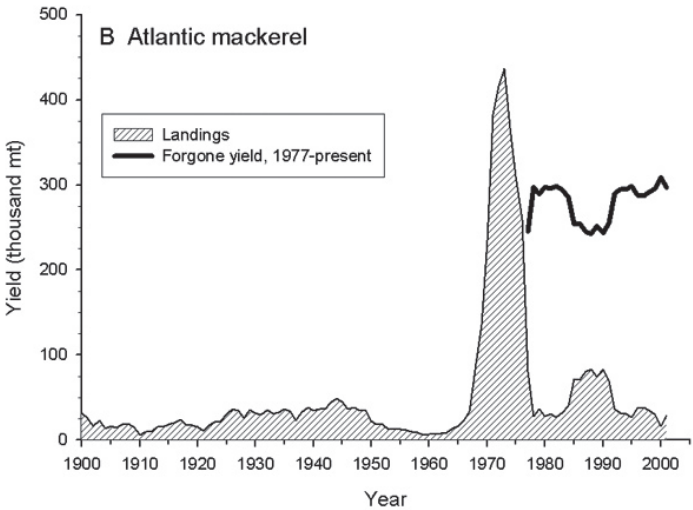


Figure 4. Total reported landings during the 20th century and forgone yields since passage of the Magnuson Act for (A) Atlantic herring and (B) Atlantic mackerel.

so, the effect of herring predation appears to be minor because haddock abundance and recruitment have increased since 1994 (NEFSC, 2001), despite high herring biomass.

Increased Fishery Yield vs Predator Consumption.—Forgone yield, the difference between long-term potential yield (MSY) and annual landings, has been substantial for herring and mackerel stocks since the passage of the Magnuson Act (Fig. 4). Herring and mackerel are important in the diets of fish, marine mammals, and seabirds in the region and comprise a significant proportion of the diet of these predators (Overholtz et al., 1991a, 2000). Estimated consumption of herring by predatory fish reached over 250,000 mt in the early 1990s after being low during the late 1970s and early 1980s (Fig. 5). If fisheries for herring and mackerel expand greatly, pelagic predators and fisheries may compete and lead to stock declines. Under this scenario, natural and fishing mor-

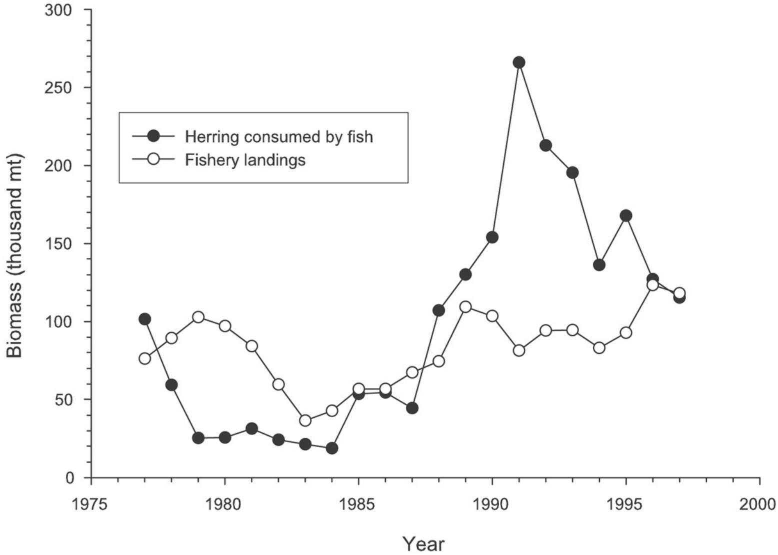


Figure 5. Estimated total biomass of Atlantic herring consumed by 12 major fish predators, 1977–1997 from Overholtz et al. (1999).

tality are compensatory for herring and mackerel (Overholtz et al., 1991b). As a result, MSY estimates for the principal pelagics that assume no compensatory mortality may be ecologically optimistic and too high. At present, pelagic predators appear to be consuming more herring and mackerel biomass than the fishery is harvesting (Overholtz et al., 2000; Link and Brodziak, 2002). Nonetheless, if this situation changes as pelagic harvests increase, management could control the risk of a mismatch between estimated MSY values and actual potential yields in a changing ecosystem by not allowing pelagic fisheries to expand too rapidly. A step-wise approach to increasing pelagic fishery yields would give managers a chance to monitor results and reduce harvests if necessary. Overall, effective management of the pelagic fisheries will require greater understanding of biological feedbacks and an adaptive harvesting approach (Overholtz et al., 1991b; Link and Brodziak, 2002).

Applying an Ecosystem Approach

The examples from the sea scallop, groundfish, and pelagic fisheries underscore the importance of trade-offs and make clear that an ecosystem approach could improve future management of New England fisheries. At a minimum, implementing ecosystem management will entail further reductions in fishing capacity, greater use of marine protected areas, continuation of fishing-effort limitations, and increased ecosystem monitoring (Fogarty and Murawski, 1998; Brodziak and Link 2002). Improved monitoring of key abiotic, biotic, and human-caused processes will require expanded oceanographic, biological, and socioeconomic data collection systems as well as additional research support. Ideally, an ecosystem-based approach will allow for simultaneous consideration of risks to target species, prey species, by-catch species, protected species, essential fish habitat, secondary effects of fishing vessels and gear, and effects on fishing communities.

Obviously, managing multiple risks in an ecosystem context will require a substantial amount of information. Fishery management institutions in New England will therefore probably need to evolve to be more explicit about decision criteria, policy strategies, and uncertainties in order to improve accountability, meet legal mandates, and document decisions about ecosystem trade-offs (Brodziak and Link, 2002).

Although the focus of this paper is on the fisheries of New England, a truly comprehensive ecosystem approach must incorporate other ocean uses and services as well. Other uses include aquaculture, research, oil and gas exploration, ocean mining, dredging, ocean dumping, energy generation, ecotourism, marine transportation, and marine defense (Sissenwine and Mace, 2003). Services include the ocean's role in hydrological cycles and as a CO_2 sink, as well as the basic existence value of living marine resources. The potential for future conflict between fishing and other uses of New England waters is considerable. For example, the current ban on oil exploration on Georges Bank will expire in 2012, so the potential benefits of oil exploration will have to be weighed against the potential risks to Georges Bank fisheries at a time when several major fish stocks are projected to be completely rebuilt.

U.S. ocean policy may soon undergo a sea change to provide greater protection of living marine resources. The U.S. Oceans Act of 2000 established a bipartisan National Ocean Commission to undertake a comprehensive review of U.S. ocean and coastal activities and develop a national ocean policy. This review is currently ongoing and may include recommendations for changes in U.S. laws designed to improve the management, conservation, and use of ocean resources; reviews of federal ocean activities; and an evaluation of the relationship between federal, state, and local governments in planning ocean activities.

Impediments to Achieving an Ecosystem Approach

Insufficient Knowledge.—The credibility of the science underpinning stock assessments is continually under attack, particularly when it involves depleted or overfished stocks. Yet, in most such cases, the argument is not so much whether the stocks are overfished as how bad the overfishing is and what the rebuilding goals should be. For example, estimating rebuilding targets for New England groundfish has proved difficult because few observations are available of the stock responses to low or even moderate fishing-mortality rates. In this and many other cases, challenging the credibility of the science has been used as an excuse to delay necessary regulatory action.

When it comes to understanding and predicting interactions within and between the biological and physical components of ecosystems, however, ecosystem science is in its infancy. Except in a few simple, well-studied systems, the impacts of a substantial change in the abundance of one species on all of the other interacting species are seldom clear. The best approach for the foreseeable future may well be to implement a few common-sense "rules of thumb" (Mace, 2001; Sissenwine and Mace, 2003), for example eliminate overcapacity; keep overall fishing-mortality rates low so that perturbations of the food web and detrimental impacts on fish habitat are small; do not disproportionately affect any trophic level; identify important species that have the greatest connectivity with other species; and maintain relatively high abundances of important prey species.

Inadequate Monitoring.—One of the essential ingredients of a holistic ecosystem approach is baseline monitoring of the biological components of the ecosystem, their associated habitat, and the relevant physical and chemical oceanographic processes.

Recently, NMFS has produced a comprehensive Marine Fisheries Stock Assessment Improvement Plan (Mace et al., 2001) that details the requirements for improving the quality of stock assessments. For the most part, it is not the level of sophistication of the models that needs improvement, but rather the type, quantity, and quality of input data. For most of the 904 stocks examined, at least basic information is available on landed catch and the size frequency of the catch, but for more than 40% of the stocks, no fishery-dependent or fishery-independent index of abundance is available, making meaningful assessments of stock status difficult. About 60% of the 904 stocks have not been assessed within the last few years, if ever, and only 13% have been assessed by means of state-of-the-art age-, size-, or stage-structured models, sometimes incorporating environmental, spatial, and seasonal effects. Although most of the commercially important species are routinely assessed, those that have never been assessed usually contribute little to total landings, although they may be important from an ecosystem perspective. In New England, a relatively high percentage (about 37%) of the 56 stocks listed in FMPs are routinely assessed with state-of-the-art models, but New England FMPs generally do not consider small-volume target species or by-catch species. A significant part of the evolution toward comprehensive ecosystem-based management plans will probably involve far greater consideration of these other species, including increased analysis of existing data and new monitoring programs, possibly at the expense of current programs focused on key target species.

DATA COSTS.—The costs of obtaining adequate data for assessment of the status of all marine species actually or potentially affected by fisheries would probably be exorbitant, probably requiring at least a 10-fold increase in current monitoring levels, with concomitant increases in scientists and technicians to collect, process, manage, and analyze the data and to communicate the results. The authors of the Marine Fisheries Stock Assessment Improvement Plan (Mace et al., 2001) struggled to find a reasonable tradeoff between such expensive "pie in the sky" objectives and the data-poor situation that currently exists for many stocks. In brief, the compromise reached was to strive to improve the assessments of primary species, to manage these through "high maintenance" management measures, and to assess and manage other species by less rigorous methods (e.g., to assess them as groups or complexes of genetically or ecologically related species or on the basis of indicator species and to manage them by indirect measures such as closed areas and seasons and gear restrictions). Even so, projected personnel requirements for stock assessment and related activities were estimated to be almost twice the current levels nationally and about 50% higher for New England stocks.

OVERCAPACITY.—In our opinion, overcapacity is the key problem to be resolved in New England fisheries. We agree with Mace (1997) and others (Garcia and Newton, 1997; FAO, 1998; National Research Council, 1999a,b; Ward et al., in press) that reductions in fleet capacity are essentially a precondition to the success of management measures designed to eliminate overfishing, minimize by-catch problems, reduce environmentally destructive fishing practices, reduce underreporting, and improve government-industry relations—all of which are also key ingredients of ecosystem-based management. Until 1994, most New England fisheries were open access and had substantial overcapacity. Edwards and Murawski (1993) estimated that the net economic value for New England groundfish in the early 1990s would have been maximized by a 70% reduction in fishing effort. Limited-entry licensing was introduced into the groundfish fishery in 1994, but the requirements for obtaining a license (recorded landings of at least 1 lb of any of several groundfish species over a 14-mo qualification period) were designed to ensure maximum participation. Of the subsequent three rounds of buybacks, the first two together cost $25 million and eliminated a total of 79 vessels and permits. The third was designed to reduce the number of latent permits (not vessels) and bought 245 permits for a total cost of $10 million. Overall, these buybacks have reduced effective fleet capacity by less than 10%, and considerable latent capacity remains (Fig. 2). Currently, the groundfish fishery includes about 1663 permits, but less than 30% of this level may be more than sufficient to land the maximum sustainable yield (Kirkley et al., 2002).

Transition Costs vs Maintaining the Status Quo.—By far the largest transition cost, in monetary and social terms, is the cost associated with eliminating overcapacity. In monetary terms, $35 million has already been spent on vessel and license buybacks in New England, but substantial overcapacity and latent capacity still remain (and the cost of buybacks required to eliminate overcapacity totally is estimated at several billion dollars). Buybacks are not the only, or even necessarily the best, solution to the problem of overcapacity, but other alternatives such as the introduction of share-based harvest-rights systems appear to be even less acceptable at present. In the meantime, substantial sums of money are being spent in attempts to avoid confronting the overcapacity problem by developing and implementing temporary, band-aid management measures and by fighting it out in the courts. Although the costs of eliminating overcapacity may be high, they are transitional in nature. On the other hand, the economic and financial costs of retaining overcapacity are ongoing and include increased costs to develop and implement management actions to address allocation conflicts, increased enforcement costs as well as diminished effectiveness of enforcement, increased in-season management, increased operating costs due to the need to travel farther to fishing grounds, increased processing and product-storage costs, and decreased product quality and prices (Ward et al., in press). If overcapacity is associated with overfishing, major economic losses will also result from forgone yields of many of commercially important species (Powers and Restrepo, 1993).

The likely social costs are perhaps the most difficult for many people to accept. For many fishing communities that have long family traditions of making a living from the sea, the status quo may no longer be a viable option. In the past, a fisherman might reasonably have expected one or more of his children to follow in his footsteps, but the combination of increased numbers of vessels, increased fishing power of vessels, and reduced fish stocks means that this expectation is no longer realistic. Indeed, the fishing fleets of many of the traditional New England fishing towns have already diminished considerably in size. Communities are being forced to restructure and find alternative sources of employment and income. The social costs of retaining current levels of overcapacity include decreased stability of the industry and dependent communities, a less stable regulatory environment, more intrusive regulations, greater uncertainty about future regulations and revenues, increased conflict on fishing grounds, decreased flexibility about where and when to fish, decreased fishing safety, and shorter season length (Ward et al., in press).

From an ecosystem perspective, increases in net benefits are unlikely to result from maintaining the status quo. In fact, the more prolonged the transition period, the greater the risks to the long-term sustainability and viability of marine ecosystems off the New England coast. In addition to making it difficult to keep landings within reasonable levels, overcapacity probably exacerbates the problems of (1) high discard rates; (2) high mortality of discards due to lack of time for careful handling of discards; (3) high cryptic mortality from encounters with unnecessarily large amounts of fishing gear; (4) greater amounts of ghost fishing from lost or abandoned gear (Ward et al., in press); and (5) fishing effects on seafloor habitats. Because these sources of mortality and habitat damage are usually not well documented, correct specification of target harvest rates may be very difficult.

The Participatory Process and Political Intervention.—As envisioned in the original Magnuson Act of 1976, the approaches used to develop FMPs in the U.S. represent one of the most participatory processes in the world. Stakeholders have numerous opportunities to provide input and comments during their development. Although the result is a laborious, expensive, and slow process, the benefits achieved from weighing all alternative management approaches and points of view are believed to outweigh the costs. It would be interesting to compare this system to one involving less public input and to evaluate the efficacy of the decisions that actually result. Despite the original intent of Congress to involve the affected public in shaping management plans, domestic fisheries issues seem to have become highly politicized over the past few decades (National Academy of Public Administration, 2002). "End-runs" are numerous, in which those who do not like the way a participatory plan is proceeding get the attention of their elected representatives, who then may exert their influence to ensure that a plan that is perceived as going "too far" is rejected or a weak one accepted.

According to Hennessey and Healey (2000), such was the case for the New England groundfish fishery in 1986. The NEFMC had submitted a plan that NOAA disapproved on the basis that it did little to prevent overfishing and was unenforceable. Subsequently, when the plan was resubmitted virtually unchanged, NOAA partially approved the plan and implemented the approved parts. According to Hennessey and Healey (2000: 201), "This abrupt reversal in NOAA's position with regard to the [plan] coincided with an act of political interference in the management process… Under intense political pressure, NOAA eventually acquiesced to a plan that its fishery experts believed was fundamentally flawed."

Aligning Public Expectation with Reality.—The preface to Mace et al. (2001) outlines two very different extreme approaches to assessment and management of fisheries. The first approach maintains moderate fisheries-research efforts and moderate-sized fishing fleets and implements only simple management measures with correspondingly simple assessment demands. The result is usually relatively low fishing-mortality targets that reduce the risks of overfishing to both target and by-catch species. In the second approach, existing data collection, management, and enforcement programs are greatly expanded to provide a knowledge base adequate to support higher fishing-mortality targets (i.e., to permit management "at the edge") while ensuring low risks to target and by-catch species as well as ecosystems. Unfortunately, the current reality is that fisheries research efforts are relatively moderate, fishing-fleet sizes and fishing effort are generally excessive (often 2–3 times greater than needed to match target fishing-mortality rates), and fishing mortality rates are at or beyond "the edge" (Fig. 6).

In an attempt to prevent fishing-mortality rates from going even further beyond the edge, more and more restrictive fishing regulations have been implemented, in an environment where funding levels have not kept pace with the need to enforce such regulations. Hennessey and Healey (2000: 203) note that "Moreover, during the 1980s, the Reagan administration, in its anti-regulatory zeal, substantially cut the budget of the NMFS. Congress not only failed to restore the agency's budget but went on to expand greatly its regulatory mandate." When the expectations from science and management are expanded and then embedded within an ecosystem-based approach, the result is

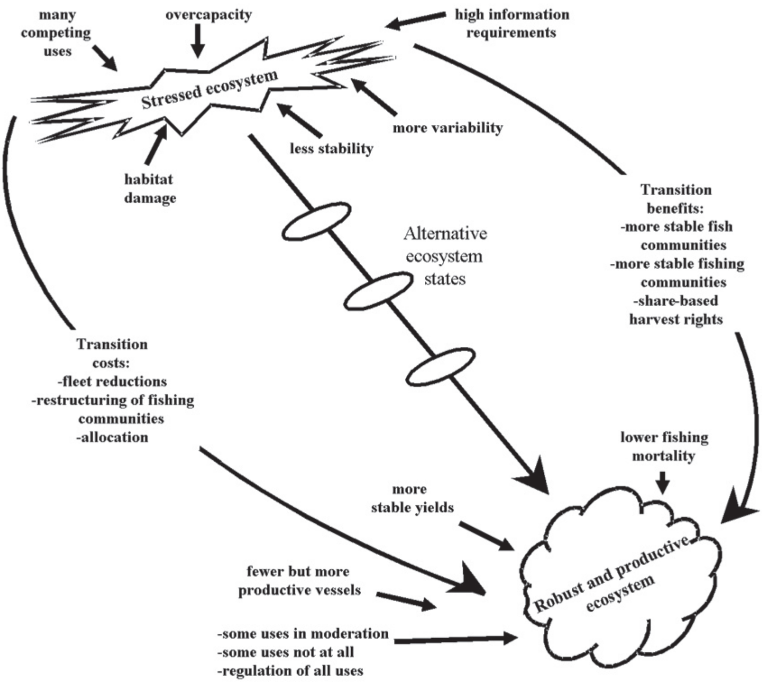


Figure 6. Costs and benefits of the transition of the New England ecosystem from its current stressed state to a robust and productive state.

obviously likely to be more than an already-overloaded system can handle. Expectations of fisheries science and management must reflect what is reasonable given realistic fiscal constraints and social costs. Is it therefore better to accept current or similar funding levels for science and management and to reduce fishing capacity substantially so that a lack of knowledge and enforcement capability will not put ecosystems in undue jeopardy, or should science and management capabilities be markedly increased to ensure that the necessary competence is available for successful resolution of current pressing problems associated with current overcapacity?

Long-Term Benefits of an Ecosystem Approach

Numerous examples exist around the world where tough transitions were made, and in hindsight, the ultimate outcome was worth the hardship. One example off the northeastern U.S. is the recovery of the striped bass (*Morone saxatilis*) fishery. Striped bass stocks were severely depleted in the 1970s and several states along the Atlantic coast imposed extremely restrictive regulations to restore the stocks. The state of Maryland banned all commercial fishing until the striped-bass resource exhibited significant signs of recovery. Nowadays, this highly valued species is so abundant that some stakeholders are worried about predation impacts by striped bass on other fish stocks.

The Atlantic sea-scallop resource represents an even more dramatic case and is a convincing example of the “shifting-baselines syndrome” (Pauly, 1995). In the early 1990s, realized fishing-mortality rates for sea scallops were estimated to be on the order of $F = 1.0–2.0$ in comparison to target fishing rates of $F_{0.1} = 0.2$ or $F_{max} = 0.25$ and a low natural mortality rate (M = 0.1). Few fishermen and managers believed that drastic reductions in F toward target fishing rates were necessary or even desirable. The scallop fishery seemed to be viable, and revenues appeared relatively high. In fact, fishermen, managers, and scientists were hard pressed to conceive of biomass levels several fold greater than recorded observations (the shifting-baseline syndrome). Some people even argued that a reduction in fishing mortality, which would lead to a larger average size of scallops in the catch, would have a detrimental effect on prices. Producers and consumers were accustomed to smaller scallops (> 30 count lb^{-1}) and larger ones were thought to be less marketable. In contrast to these expectations, scallop biomass has increased markedly (14-fold in the closed areas during 1994–1998) since the mid-1990s (Murawski et al., 2000). Average scallop size has also increased, and the larger, 10-count scallops now command premium prices.

The scallop, groundfish, and pelagic fisheries of New England must be managed with a constancy of purpose to be robust and productive. If the New England fishing industry is to survive the transition from overharvesting depleted resources with excessive fishing capacity to highly productive, robust stocks and economically vibrant fisheries (Fig. 6), conservation goals must be paramount. Achieving these goals will require reducing habitat damage, restoring exploited and unexploited fish stocks, and decreasing or in some instances phasing out some competing uses of living marine resources. Overall, the importance of maintaining ecosystem processes and functions must be recognized, agreed to, and acted upon by all stakeholders.

Although applying a holistic ecosystem approach to management of New England marine fisheries should reduce conflicts and improve stakeholder satisfaction, such an approach will, in practice, be tempered by political interests and the willingness of the public to pay for increased management and resource costs. In the short term, rebuilding plans and essential-fish-habitat plans will be needed to meet conservation goals. Unambiguous plans with clear goals are essential to ensuring that the transition to more stable fish and fishing communities will be achieved rather than postponed for future generations to deal with. One of the primary impediments to restoring the productivity of marine ecosystems off New England is the perceived transition costs, but achieving sustainability will require that fishing effort be substantially reduced so that low fishing-mortality rates can be maintained. Fishery capitalization goals must be set and achieved to ensure that fishery yields are more stable and remaining fishing vessels are prosperous. Share-based harvest rights systems will be needed that allocate fishing opportunities in a rational manner. When the finfish and shellfish stocks supporting New England fisheries are rebuilt to B_{MSY}, the controversies generated by ecosystem trade-offs should greatly diminish.

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